DETECTION OF COMPACT NUCLEAR X-RAY EMISSION IN NGC 4736

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ABSTRACT

We report the results from a deep *ROSAT* PSPC observation of LINER galaxy NGC 4736. Two bright sources are detected, separated by only about $1'$, with the brighter one coinciding with the center of the galaxy. Neither source shows apparent X-ray variability on time-scales of minutes to hours in the *ROSAT* band. Simple power-law models, typical of AGN X-ray spectra, produce poor fits to the observed X-ray spectrum of the nuclear source. The addition of a Raymond-Smith component improves the fits significantly. This is consistent with the presence of hot gas in the nuclear region with $kT \simeq 0.3$ keV, in addition to a compact nuclear source. However, a careful examination of the residuals reveal apparent features at low energies (< 0.25 keV). We find that the addition of a narrow emission line at about 0.22 keV is a significant improvement to the parameterization of the spectrum. We examine the results in the light of the accuracy of the PSPC spectral calibration. The derived photon index is about 2.3, which is similar to those for Seyfert 1 galaxies measured in the *ROSAT* energy range. On the other hand, the 0.1-2 keV luminosity for the compact source is only about 3.4×10^{39} $erg\ s^{-1}$, much fainter than typical Seyfert galaxies. We discuss the implications of these results on the connection between LINERs and AGNs.

The off-center source is transient in nature. It has a hard X-ray spectrum, with a photon index of about 1.5, so is likely to be an X-ray binary. There is still some ambiguity regarding its association with the galaxy. If it is indeed located in the galaxy, the 0.1-2 keV luminosity would be greater than 5.1×10^{38} $erg\ s^{-1}$, making it a stellar-mass black hole candidate.

Subject headings: galaxies: individual (NGC 4736) — galaxies: active — galaxies: nuclei — X-rays: galaxies

1. Introduction

The active galactic nucleus (AGN) phenomenon expresses itself very clearly at X-ray wavelengths. X-ray emission from AGN is thought to be due to the accretion of surrounding

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matter onto a massive central black hole. The X-ray luminosities of AGNs span many decades. Quasars are the most luminous among the class, with X-ray luminosities above $10^{45} erg\ s^{-1}$. Seyfert galaxies, on the other hand, are much fainter, with typical luminosities of $10^{43-45} erg\ s^{-1}$. However the least luminous ones can be as faint as $10^{40-41} erg\ s^{-1}$ (Cui et al 1996b), which is already close to the luminosity of bright "normal" galaxies (Fabbiano 1995). Only about 1% of luminous galaxies are AGNs in a classical sense (Weedman 1977). It is therefore natural to ask if AGN activity stops abruptly at Seyfert galaxies, or extends to lower luminosities, more specifically, to the realm of "normal" galaxies.

X-ray observations of nearby galaxies sometimes show relatively bright nuclear emission (Fabbiano 1989), similar to that detected in Seyfert galaxies. Optical spectroscopic surveys of these galaxies show that as many as 10–20% of the bright ones may be active, but at a much lower level than classical AGNs. Many of them have optical spectra characteristic of low ionization emission-line regions (LINERs) (Heckman 1980; Staufer 1982; Keel 1983a, b; Filippenko & Sargent 1985; Véron-Cetty & Véron 1986; Phillips et al. 1986). These surveys also show that LINERs are very common among ellipticals and early-type spirals, about 80% of Sa galaxies, over 40% of Sb galaxies, and one third of all spiral galaxies. Perhaps they are the missing link between Seyfert and "normal" galaxies.

LINERs seem to make up a heterogeneous class: while some show AGN-like activity, the observed nuclear activity in others may be explained by other physical processes, such as shock heating, cooling flow, or photoionization by hot stars at the center of the galaxy, without invoking an AGN scenario (see a review by Filippenko 1994). Systematic investigations of AGN-like activity in LINERs have been carried out primarily in the optical (e.g., Filippenko & Terlevich 1992; Ho, Filippenko, & Sargent 1993), while observations at higher energies, such as UV and X-rays, have only begun recently (Maoz et al. 1995; Koratkar et al. 1995).

To address this issue, we studied a nearby Sab galaxy NGC 4736 (Sandage & Tammann 1974). NGC 4736 has the optical spectrum of a LINER (Heckman, Balick, & Crane 1980; Heckman 1980), and is known optically for its bright nucleus and high surface brightness in compact spiral arms. Its optical similarities to the Seyfert galaxy NGC 1068 make it "the best candidate for an ex-Seyfert" (Keel & Weedman 1978). Recently, Maoz et al. (1995) reported the detection of compact nuclear UV emission in NGC 4736 using the Faint Object Camera on the *Hubble Space Telescope* (HST), which suggests the presence of an AGN-like continuum source or a compact stellar cluster at the center of this galaxy.

In this paper, we present the results from a deep *ROSAT PSPC* observation of NGC 4736. The X-ray and radio data are described and presented in § 2. Detailed analyses are carried out in § 3, and the results discussed in § 4. Finally, we conclude by summarizing the main results in § 5.

2. Data

NGC 4736, along with a few other high latitude, nearby, face-on spiral galaxies, was chosen to be observed by the *ROSAT PSPC* as part of a systematic investigation of the distribution of soft diffuse X-ray emission, thus the distribution of hot gas, in the disks of "normal" spiral galaxies (Cui 1994; Cui et al. 1996a). Some basic data on NGC 4736 are summarized in Table 1.

During the observation (RP600050), the pointing direction ($RA(J2000) = 12^h50^m50.4^s$, $DEC(J2000) = +41^d06^m36.0^s$) is slightly off the center of the galaxy (see Table 1). The total on-source time is about 96 ks. Sporadic short term enhancements of unknown origin (Snowden et al. 1994) dominated the total count rate for a significant fraction of the observation. The data were also severely contaminated by scattered solar X-rays. While it is essential to understand and remove these non-cosmic X-ray events for studying diffuse X-ray emission from this galaxy (Cui et al. 1996a), it is not as critical for the study of individual bright sources because the conventional "annulus background subtraction" technique can be applied. However, in order to minimize possible systematic effects, such as non-uniform distribution of non-cosmic events over the detector, we chose to exclude the time intervals when the total count rate was 20 $count\ s^{-1}$ higher than the "quiescent" level. This eliminated short-term enhancements and the worst instances of scattered solar X-rays; it leaves us with an exposure time of about 87 ks. The X-ray image (with a pixel size of $7.5''$) was re-projected it to epoch B1950, and was interpolated to a smaller pixel size. The final image of the central region of the galaxy is shown in Fig. 1, for the 0.1-2.0 keV energy band.

In addition to the X-ray data, we have also obtained interferometric H I 21 cm data (Braun 1995) and JCMT CO (2→1) data for this galaxy. A full discussion and analysis of these data will be presented elsewhere. In this paper, we use these distributions primarily to constrain the internal absorption of soft X-rays by gas within the galaxy.

3. Analysis

The X-ray image clearly shows two closely-spaced sources near the center of the galaxy. They are only separated by about $1'$, with the brighter one coinciding with the center of the galaxy (within the *ROSAT* pointing accuracy, usually $\sim 10''$).

3.1. Spatial Analysis

To estimate the spatial extent of the detected sources, we made linear cuts through them along both east-west and south-north directions, with $7.5'' \times 7.5''$ square bins. Fig. 2 shows the linear profiles of both sources. Note that only one profile for the off-center source is shown because of heavy "contamination" by the central source along the other direction. The solid-lines are the

broad-band averaged theoretical point spread functions (PSFs) at the locations of the sources. They fit the measured profiles well around the peaks, indicating that the sources are consistent with being point-like. Broad wings on the source profiles are apparent for both sources, and are caused by the difficulty of separating them, as well as by the diffuse X-ray emission which is very strong at the center and hardly detectable in the background annulus (Cui et al. 1996a). For such a long exposure, the source position can be accurately determined by fitting the source profile with PSF (to an accuracy much better than the spatial resolution of the *PSPC*). The best determined positions of the sources are listed in Table 2. In this case, errors are dominated by the *ROSAT* pointing uncertainty.

3.2. Timing and Spectral Analysis

Because two sources are so close to each other, we chose to extract source counts within a pie-shaped region (see Table 2) centered on one source to avoid "contamination" from the other. The background counts were obtained from an annulus centered on the galactic center with radii of $3.3'$ and $7.5'$, which is nearly free of any other bright sources (only one was detected and removed).

Neither source displays apparent X-ray variability on timescales of minutes to hours.

For each source the total counts were accumulated into a 256-channel, pulse-height-invariant spectrum. We ignored energy channels below 9 and above 212, and rebinned the remaining channels into 26 energy bins using the scheme adopted by the *ROSAT* Standard Analysis Software System.

For the central source, the high signal-to-noise ratio (S/N) of the resulting X-ray spectrum made it particularly challenging to adequately model it because systematic uncertainties in the instrument calibration become significant in this case. We tried to fit the spectrum with simple models, such as blackbody (BB), power-law (PL), and thermal bremsstrahlung (TB), using Morrison & McCammon cross-sections (1983) for absorption, but none of them individually provided an adequate fit. Significant improvement was achieved with the addition of a Raymond-Smith component (RS; Raymond & Smith 1977) which approximates the X-ray emission from an optically-thin hot plasma. This is consistent with the reported detection of strong diffuse X-ray emission in the inner disk of NGC 4736 (Cui et al. 1996a), because a likely origin of such emission is the thermal emission from million-degree gas present in the central region of the galaxy. As discussed above, the diffuse component should remain in the present data. Therefore, at least one RS component is required to adequately model it. A combination of PL (or TB or BB) and RS is thus the simplest plausible model to fit the observed X-ray spectrum, with PL (or TB or BB) representing the spectrum of the compact source itself. Depending on the geometries and positions of the X-ray emitting regions in the galaxy, these two components may be absorbed by different amount of matter along the line-of-sight. We proceeded to fit the spectra with such

two-component models,

$$I_{observed} = I_s e^{-\sigma N_H^s} + I_{RS} e^{-\sigma N_H^{RS}}, \tag{1}$$

where s is either PL, TB, or BB, and assuming solar abundances for RS. Both PL+RS and TB+RS fit the data equally well, and the best-fit parameters are shown in Table 3. Clearly, neither fit is statistically acceptable. The problem can be better demonstrated by Fig. 3a, which shows the observed X-ray spectrum of the central source, and the best-fit PL+RS model. Upon examination of the residual, the model deviates from the data very significantly at the low energy portion of the spectra (< 0.25 keV), even though it fits the high energy portion reasonable well. We are not certain if this is a real effect, or calibration artifacts, which would be more prominent in high S/N data (we have used the 92mar11 response matrix, as instructed in the *ROSAT* Users' Handbook). Spectral calibration uncertainties are known to be larger at lower energies (see the *ROSAT* Users' Handbook). As recommended, a 2% systematic uncertainty was added to the data to represent the best estimated uncertainty in detector response matrix calibration.

In order to model the low-energy end of the spectrum, we added a soft BB component to the two-component models. Unfortunately, no significant improvement was obtained. Decent fits were made possible with the addition of a Gaussian line feature (centered at $E_c \simeq 0.22$ keV with zero width; no absorption was applied to this component) to the two-component models. This feature might be associated with one or more of emission lines of highly ionized Fe, Si, Mg, and S in an optically thin plasma. We then experimented with adjusting abundances of these elements in the RS model and in the absorption cross section calculation in an attempt to remove it, but failed to get a reasonable fit. This seems to suggest that the Gaussian component is a calibration artifact. The best-fit model (PL+RS+GAU) is plotted in Fig. 3b, and the parameters are shown in Table 3.

We experimented with other more complicated models that have been proposed for AGNs, including the partial-covering models that seem to fit the observed AGN X-ray spectra well (Ceballos & Barcons 1996). However, none provided significant improvement over the simple models. The large discrepancies between the models and the observed spectrum at energies below ∼0.25 keV are hardly reduced by adopting these complicated models.

Similar spectral analysis was carried out for the off-center source. Fig. 5 shows the observed X-ray spectrum for this source, along with the best-fit model (PL+RS). In this case, no Gaussian line feature was required to model the observed X-ray spectrum (perhaps due to relatively low S/N of the data). The results are summarized in Table 3.

4. Discussion

As expected (Cui et al. 1996a), the diffuse component is dominated by the 1/4 keV emission, as evidenced by the temperature of the RS component (about 0.3 keV). It accounts for about 30-35% of the total observed 0.1-2.0 keV flux. The $N_{\rm H}$ values are not very well constrained in our case, although small values seem to be preferred. The radio data show, however, that although

the integrated H I emission shows a decline in *apparent* atomic column density inward of about $40''$ radius from about $N_{HI} = 2. \times 10^{21}\ cm^{-2}$ to less than about $10^{20}\ cm^{-2}$ (see Fig. 1a and Fig. 4), there are indications that the H I at radii less than about $60''$ is already quite opaque so that *actual* H I columns are likely to be several times larger. Comparable column densities of molecular hydrogen are inferred from CO emission at radii of about $50''$. These appear to increase roughly exponentially to smaller radii (as shown in Fig. 4 utilizing the data of Gerin et al. 1991 and assuming a CO 1-0 to $N_{\rm H}$ conversion factor of $2.3 \times 10^{20}\ cm^{-2}/K\ km\ s^{-1}$). Although some authors have postulated a "hole" in the molecular gas distribution at small radii (Smith et al. 1991), there is as yet no observational evidence for such a configuration of the neutral gas. How can we reconcile these seemingly conflicting results? There are two possibilities: (1) the $N_{\rm H}$ distribution in NGC 4736 is clumpy on angular scales smaller than the beam sizes of the H I and CO surveys, and there is a relatively clear path toward the nuclear source, or (2) the detected source is located off the galactic nucleus, and sits high above molecular clouds in the region. Our results alone cannot distinguish between these scenarios.

We cannot rule out a purely thermal origin of the central source. Thus, the shock-heating scenario is still very likely. Hot gas is definitely present in the region, and produces strong diffuse X-ray emission (Cui et al. 1996a). On the other hand, a power-law X-ray source at the galactic center is also possible to account for the bulk of the emission. The derived power-law photon index for the source is similar to those for typical Seyfert 1 galaxies measured in the *ROSAT* energy range (Turner, George, & Mushotzky 1993). With an assumed distance of 4 Mpc, the observed 0.1-2 keV luminosity of the source is only about $3.4 \times 10^{39} erg\ s^{-1}$, much lower than that of typical Seyfert galaxies. Under AGN settings, the low X-ray luminosity is perhaps due to an intrinsically lower mass accretion rate in the galaxy due to a lack of "fuel" in the region. Assuming an X-ray conversion efficiency of 10%, a lower limit on the mass accretion rate can be estimated as

$$\dot{\rm M} \geq \frac{10 L_{0.1-2.0keV}}{c^2}, \tag{2}$$

with $L_{0.1-2.0keV} \simeq 3.4 \times 10^{39} erg\ s^{-1}$ (see Table 3). The lower limit is thus $\sim 6 \times 10^{-7} M_{\odot}\ yr^{-1}$, which does not appear to be in conflict with any other observational lower limits on AGN activity. Another possibility is that the accretion process in this galaxy operates in a so-called "advection-dominated regime" in which the bulk of released energy is advected with the gas present in the region into the central black hole; little is radiated away in the form of X-rays (e.g., Narayan & Yi 1995). This model could provide a natural explanation for the presence of hot gas in the region. The advection-dominated accretion may be common among low-luminosity Seyfert galaxies and LINERs, in fact, it appears to be what takes place at the center of our own Galaxy, based on a multi-wavelength spectral analysis of Sagitarrius A^* (Narayan, Yi, & Mahadevan 1995).

The nucleus of NGC 4736 shows signs of being active: it is bright in Hα, as shown in Fig. 6 (Pogge 1989), and radio continuum emission (see Fig. 1b). Maoz et al. (1995) reported the detection of compact nuclear UV emission in NGC 4736 in a *HST* observation. In fact, they detect two unresolved sources of comparable brightness separated by about $2.5''$. The source

surrounded with diffuse emission is presumed to coincide with the optical nucleus of NGC 4736, while the second source is suggested to be the nucleus of a recently merged sub-system. With the unprecedented spatial resolution of the *HST*, this detection provides evidence for the existence of a non-stellar (or extremely compact stellar) continuum source. We have now detected luminous compact X-ray emission from the region, and the measured position of the central X-ray source is consistent with it being located at the galactic nucleus (see Tables 1 and 2). However, because the spatial resolution of the *ROSAT PSPC* is poor, we cannot rule out the possibility that the observed X-ray emission may be the integrated contribution from luminous X-ray binaries near the galactic center.

Compact nuclear X-ray emission has also been detected in other LINERs. Koratkar et al. (1995) studied five low-luminosity AGNs (LLAGNs) including two LINERs to address specifically the issue of whether the dominant X-ray production mechanism is the same at all luminosities in AGNs. Soft X-ray emission was detected in all galaxies. The high-resolution *HRI* images show that the emission is mostly or entirely confined to the nucleus. The observed *ROSAT PSPC* spectra of the LINERs and one Seyfert 1 galaxy in their sample are similar, and can be fit by simple power-law models with relatively low internal absorption. Like NGC 4736, the derived photon indices and absorbing column densities are similar to those for luminous Seyfert 1 galaxies measured in the *ROSAT* energy range (Turner, George, & Mushotzky 1993). Evidence is strong to support that the physical processes in producing X-rays in LLAGNs (including a significant fraction of LINERs) are the same as in the luminous objects, although studies of a larger sample of LLAGNs are clearly required to draw any definitive conclusions.

What is the nature of the off-center source? The observed 0.1-2.0 keV luminosity (internally absorbed) is $\sim 5 \times 10^{38} erg\ s^{-1}$, making it a very luminous X-ray source, if it is indeed a single point source. The hard power-law spectrum seems to suggest that it is likely to be a X-ray binary. The mass of the primary in the binary system can then be estimated as

$$M = M_{\odot} \frac{L}{L_E}, \tag{3}$$

where L_E is Eddington luminosity for a $1 M_{\odot}$ accreting object. Assuming an Eddington luminosity appropriate for pure electron scattering, $\sim 1.3 \times 10^{38} erg\ s^{-1}$, the *absorbed* X-ray luminosity (see Table 3) would require the mass to be larger than $\sim 4 M_{\odot}$, making it a stellar-mass black hole candidate. Similar luminous X-ray sources have also been detected in several other nearby spiral galaxies (see Fabbiano 1995 for a review).

This source is located on the inner H I ring, to the north-west of the nuclear source. Many compact radio sources were detected along the ring, with both thermal and non-thermal radio continuum spectra (Duric & Dittmar 1988). They are thought to be thermal bremsstrahlung emission from compact H II regions associated with hot, young stars, and synchrotron radiation from young supernova remnants respectively, both of which indicate active star formation in the ring. High star formation rates are also supported by the observed Hα emission in the region (Pogge 1989). The detected X-ray source is only a few arcseconds away from one of the thermal

radio sources, as shown in Fig. 6, which is associated with a compact H II region. The poor spatial resolution of the *ROSAT PSPC* prevents a definitive identification with the compact radio source.

The proximity of this source to the nuclear source might also suggest some causal relation: is it some sort of ejecta or jet from the central source. The observed X-ray morphology, as shown in Fig. 1, seems to argue against it, but high spatial resolution is clearly needed to address this question.

It is also conceivable that what we are seeing are the cores of two merged galaxies, both of which emit strongly in X-rays. This model may provide a natural explanation for the formation of the prominent ring structures in this galaxy (Mulder & Van Driel 1993), since the disturbance caused by the galaxy merging process is likely to produce strong shock waves. These same shocks might also trigger star-formation in the rings, as supported by radio and Hα observations (Duric & Dittmar 1989; Pogge 1989). In this case, the observed off-center UV source (Maoz et al. 1995) may simply be a circumnuclear star cluster.

However, the derived $N_{\rm H}$ values are uncomfortably low (lower than that due to the foreground interstellar medium in our Galaxy; see Table 1). When we fixed the $N_{\rm H}$ to the Galactic value, the fits became worse. This seems to indicate that the source is closer to us than the galaxy, even though the probability of a foreground X-ray source fortuitously lining up with the nucleus of the galaxy is very small. There are, however, no known Galactic X-ray sources in this direction. Of course, it may be a transient source that went into a relatively long and steady outburst state when observed by the PSPC, similar to 4U1630-47 (a black hole candidate), as currently seen by the All-Sky Monitor on the *Rossi X-ray Timing Explorer*. When we were about to submit this paper, the *ROSAT* HRI image of NGC 4736 became available (RH600678, which was carried out roughly 4 years after the PSPC observation). As expected, the HRI image shows a bright X-ray source at the galactic center, but the off-center source had disappeared completely, which supports its transient nature. Instead, another source is detected about the same distance away from the nucleus, but to the west and slightly south. (We have carefully checked the orientation of the observation by using the bright X-ray sources in the field). Is this consistent with the proper motion of a nearby star? If so, the star would have moved an angular distance of $\sim 25''$ in ~ 4 years, which would imply a distance (of the source from us) less than $\sim$ 13 pc, assuming a maximum tangential velocity of 400 $km\ s^{-1}$. As a result, the observed X-ray luminosity would be less than $\sim 5 \times 10^{27}\ erg\ s^{-1}$, which is still consistent with stars with X-ray emitting coronae (e.g., Schmitt et al. 1990). It cannot be a flare star, however, because no strong X-ray variability was measured. We have also searched, and have not found any reported recent supernovae in NGC 4736. It is more likely, therefore, that both X-ray sources are associated with the galaxy itself, as supported by their excellent alignment with the nuclear source. This would provide strong evidence that the inner H I ring (at which both sources are located) is indeed quite active.

5. Conclusions

We have presented and discussed the results of our analysis of a deep *ROSAT* observation of the nearby galaxy NGC 4736 to investigate possible AGN-like activity in its nuclear region, as suggested by studies of this galaxy at other wavelengths. Our main results can be summarized as follows:

- Two bright X-ray sources are detected in the central region of NGC 4736. Their X-ray radial profiles are consistent with the PSFs of the *ROSAT PSPC*, and the separation is estimated to be about 1 kpc. The brighter source is consistent with being at the nucleus, suggesting that it may perhaps represent the non-stellar continuum source that powers the observed nuclear emission at various wavelengths.
- The detailed spectral analysis show that the observed X-ray emission from the nuclear region can be attributed both to a central source and hot gas present in the region, with the central source contributing the bulk of the observed 0.1-2.0 keV luminosity. The X-ray spectrum of the off-center source is harder. It is likely to be a luminous, transient X-ray binary. Then, the measured X-ray luminosity would make it a stellar-mass black hole candidate.

Combining our results with those from observations of NGC 4736 at other wavelengths, particularly the *HST* observation, evidence is strong for the presence of a non-stellar continuum source at the nucleus of the galaxy, similar to those thought to exist in Seyfert galaxies.

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Table 1. Basic Data on NGC 4736

Name	Value	References
Type	Sab	Sandage & Tammann 1987
RA (J2000)	12^h 50^m 53^s	Sandage & Tammann 1987
DEC (J2000)	41^d 07^m 17^s	Sandage & Tammann 1987
Galactic $N_{\rm H}$ ($10^{20} cm^{-2}$)	1.4	Dickey & Lockman 1990
Distance	4 Mpc	e.g. Duric & Dittmar 1989
Major Diameter	$14'$	Nilson 1973
Minor Diameter	$12'$	Nilson 1973
H I/H II ring	$40''$-$60''$	Mulder & Van Driel 1993
Outer H I ring	$4'$-$6'$	Mulder & Van Driel 1993
Distance scale	$\sim 19 pc/1''$	assuming a distance of 4 Mpc

Table 2. The Detected Sources

Quantity	Nuclear Source	Off-center Source
RA (J2000)[1]	$12^h\ 50^m\ 52^s$	$12^h\ 50^m\ 48^s$
DEC (J2000)[1]	$+41^d\ 07^m\ 10^s$	$+41^d\ 07^m\ 35^s$
Remaining Exposure Time (ks)	87	87
Extracted Source Counts	17432	1432
Extracted Fraction[2]	80%	50%
Hardness Ratio[3]	0.026 ± 0.008	0.135 ± 0.026

[1]Errors (not shown) are dominated by the *ROSAT* pointing uncertainty ($\sim 10''$; see text).

[2]Fractional area of the pie-shaped region in a circle.

[3]Hardness ratio is defined as $(H - S)/(H + S)$, where H is the total counts in energy channels 41-200, and S in channels 8-40.

Table 3: Results of Spectral Analysis[1]

Source	Model	N_H^s $10^{20} cm^{-2}$	α	kT^{TB} keV	N_H^{RS} $10^{20} cm^{-2}$	kT^{RS} keV	Line Energy keV	Line Width keV	χ^2/dof	F^2	L^2	f_s^2 %
Nuclear	PL+RS+GAU	6^{+10}_{-3}	$2.3^{+0.5}_{-0.4}$	–	3^{+20}_{-2}	$0.31^{+0.04}_{-0.16}$	$0.224^{+0.003}_{-0.004}$	0	54.6/21	17.8	3.4	58
	PL+RS	2.0	2.5	–	1.4	0.42	–	–	124.3/24	–	–	–
	TB+RS+GAU	4^{+6}_{-2}	–	$1.5^{+2.2}_{-0.4}$	5^{+58}_{-4}	$0.29^{+0.03}_{-0.15}$	$0.225^{+0.002}_{-0.003}$	0	56.9/21	17.2	3.2	54
	TB+RS	1.3	–	0.7	1.2	0.44	–	–	182.0/24	–	–	–
Off-center	PL+RS	$0.4^{+0.4}_{-0.4}$	$1.5^{+0.4}_{-0.2}$	–	48^{+133}_{-48}	$0.4^{+0.4}_{-0.2}$	–	–	32.9/24	2.62	0.51	76
		1.4 (fixed)	$1.8^{+0.1}_{-0.1}$	–	1.4 (fixed)	$0.7^{+0.3}_{-0.2}$	–	–	46.4/26	–	–	–
	TB+RS	$0.2^{+0.4}_{-0.2}$	–	4^{+16}_{-2}	46^{+66}_{-46}	$0.4^{+0.4}_{-0.3}$	–	–	33.4/24	2.64	0.51	79
		1.4 (fixed)	–	$1.3^{+0.2}_{-0.3}$	1.4 (fixed)	$0.7^{+0.7}_{-0.4}$	–	–	55.3/26	–	–	–

[1] Uncertainties represent the 90% confidence interval.

[2] F: the total observed 0.1-2.0 keV flux in units of $10^{-13} erg\ s^{-1} cm^{-2}$; L: the corresponding X-ray luminosity in units of $10^{39} erg\ s^{-1}$, calculated for an assumed distance of 4 Mpc; and f_s: the fractional source (PL or TB) contribution. Flux and Luminosity have been corrected for insufficient source-count extraction (see discussion in § 2).

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Fig. 1.— X-ray image of the central region of NGC 4736 in the 0.1-2.0 keV energy band (in units of source counts), overlaid with (a) contours of apparent H I column density from 7.5 to 20.0 with a step size of $2.5 \times 10^{20} cm^{-2}$, and (b) contours of 21 cm radio continuum emission with brightness 2.0, 2.8, 4.0, 5.6, 8.0, 11.2, and 16.0 mJy/beam (the beam size is $15''$). Note that the X-ray peak is arbitrarily aligned with the radio continuum peak with a $10.9''$ shift in RA and $2.6''$ shift in DEC, which is within the $ROSAT$ pointing uncertainty.

Fig. 2.— Linear profiles of the nuclear source along (a) the east-west and (b) north-south directions, and (c) the off-center source along the north-south direction, with a square pixel size of $7.5''$. The solid lines are the broad-band averaged theorectical PSFs at these locations. The broad wings are perhaps due to diffuse X-ray emission in the region, as well as due to the difficulty of separating two sources (see text).

Fig. 3.— X-ray spectrum of the nuclear source. The solid-line histograms represent the best-fit models to the data: (a) PL+RS and (b) PL+RS+GAU.

Fig. 4.— Radial profiles of the *apparent* absorbing column density due to atomic and molecular neutral hydrogen in NGC 4736 (see text).

Fig. 5.— X-ray spectrum of the off-center source. The solid-line histogram represents the best-fit PL+RS model to the data.

Fig. 6.— Overlay of the detected X-ray sources in color on the image of compact radio continuum sources detected in the region, along with Hα contours, taken from Duric & Dittmar (1988). The X-ray image was smoothed with a $52.5'' \times 52.5''$ square box filter. Note that the X-ray image is shifted by the same amount as in Fig. 1.